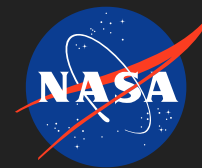


Wide-Bandgap III-V Materials for Multijunction Solar Cell Applications



Completed Technology Project (2015 - 2018)

Project Introduction

My proposal aims to address cost and efficiency issues associated with solar technology for space applications as well as its potential for positive global environmental impacts. The goal of this proposal aligns well with NASA's objectives outlined in the STR TABS for Space Power & Energy Storage (TA03). Three individual but highly complementary research projects are proposed that will culminate in an integration of all three ideas into two demonstrative triple junction solar cells. For space applications, high specific power is a key requirement for power generation. While some types of solar technology, such as Si single junction, organic, and dye-sensitized solar cells, achieve relatively low cost, they are quite limited in efficiency. Multijunction solar technology can achieve a much larger efficiencies and specific power by stacking solar cells consisting of different bandgap materials to collect a broad portion of the solar spectrum. Multijunction cells are typically made from III-V materials, which are quite expensive relative to alternatives, such as Si and organics. To make this technology more competitive for both space and terrestrial applications, we must lower the cost per watt, which can be achieved either by reducing cost or improving efficiency. The first two projects aim to improve efficiency through the introduction of a wide bandgap top junction to better collect the higher energy photons in the solar spectrum. The two materials proposed to study here are $\text{Al}_x\text{In}_{1-x}\text{P}$ ($x=0.36-0.42$, hereafter referred to as AlInP) with bandgaps near 2.34 eV and $\text{In}_y\text{Ga}_{1-y}\text{P}$ ($y=0.25-0.37$) with bandgaps around 2.15 eV. Although AlInP pn-junctions have not been previously studied for photovoltaic applications, this material boasts the largest direct bandgap of the III-arsenide/phosphides, making it a highly attractive top junction candidate. Conversely, $\text{In}_x\text{Ga}_{1-x}\text{P}$ has already been studied quite extensively and used in space applications, though only for the $x=0.49$ composition, as it is lattice matched to commercially available GaAs substrates. Metamorphic $\text{In}_x\text{Ga}_{1-x}\text{P}$ with $x=0.36-0.42$ remains largely unstudied, as it is not lattice matched to common substrate which necessitates complex graded buffers to achieve these compositions with minimal strain-induced crystalline defects that can harm solar cell performance. Recent advancements in graded buffer growth techniques have enabled investigation of this promising material. These compositions are of particular interest for their larger bandgaps, and direct absorption processes, similar to AlInP . This proposal seeks to study and optimize the growth conditions and device structures of AlInP and metamorphic InGaP solar cells. The third project focuses on reducing cost through the integration of III-V cells onto Si for its low cost and established manufacturing infrastructure. Previous studies on $\text{GaAs}_{0.7}\text{P}_{0.3}$ solar cells grown on GaP/Si templates indicate challenges with extended crystalline defect nucleation upon relaxation of GaP on Si. Here we propose to study the evolution of these defects through GaP solar cell growth on both GaP/Si templates and native GaP substrates. The characterization of solar cell performance and material quality will enable a direct comparison between growth on the two substrates to help determine how these defects nucleate and evolve throughout growth. All samples will be grown via

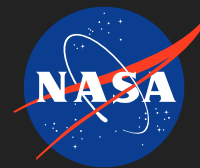


Wide-Bandgap III-V Materials
for Multijunction Solar Cell
Applications

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Wide-Bandgap III-V Materials for Multijunction Solar Cell Applications



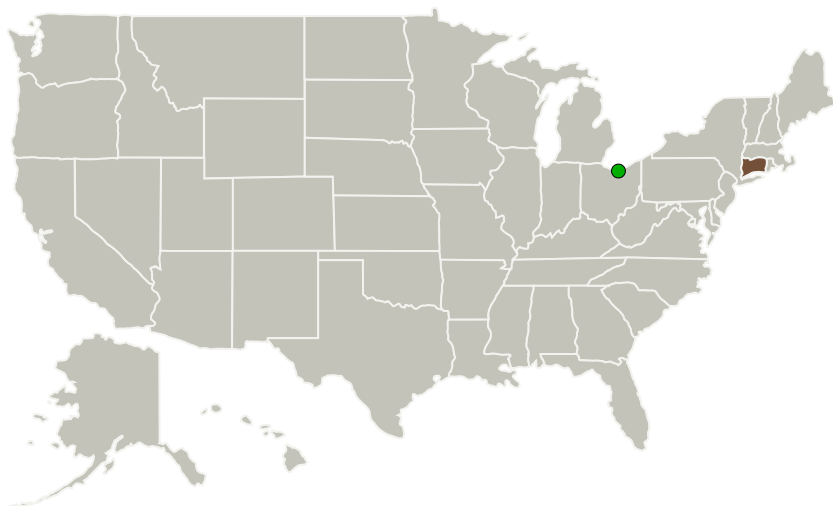
Completed Technology Project (2015 - 2018)

molecular beam epitaxy. Devices will be characterized for both solar cell performance as well as material quality, the first of which will be determined with lighted and dark current-voltage and internal quantum efficiency measurements. Microstructural characterization carried out with Hall effect measurements, photoluminescence, electron beam-induced current, and atomic force, Nomarski, scanning, and transmission electron microscopies.

Anticipated Benefits

This project aims to address cost and efficiency issues associated with solar technology for space applications as well as its potential for positive global environmental impacts. This work aims to improve efficiency through the introduction of a wide bandgap top junction to better collect the higher energy photons in the solar spectrum. The project also focuses on reducing cost through the integration of III-V cells onto Si for its low cost and established manufacturing infrastructure.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Yale University	Lead Organization	Academia	New Haven, Connecticut
● Glenn Research Center(GRC)	Supporting Organization	NASA Center	Cleveland, Ohio

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Yale University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

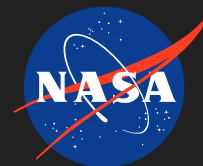
Principal Investigator:

Mark N Reed

Co-Investigator:

Michelle Vaisman

Wide-Bandgap III-V Materials for Multijunction Solar Cell Applications



Completed Technology Project (2015 - 2018)

Primary U.S. Work Locations

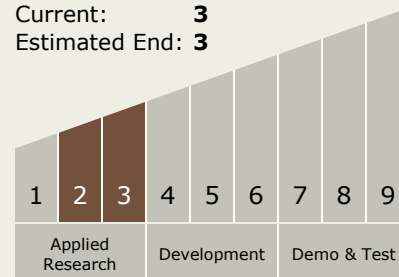
Connecticut

Project Website:

<https://www.nasa.gov/strg#.VQb6T0jJzyE>

Technology Maturity (TRL)

Start: 2
Current: 3
Estimated End: 3



Technology Areas

Primary:

- TX03 Aerospace Power and Energy Storage
 - TX03.1 Power Generation and Energy Conversion
 - TX03.1.1 Photovoltaic

Target Destinations

The Moon, The Sun